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Subendocardial Resection for Refractory Ventricular Tachycardia: Effects on Ambulatory Electrocardiogram, Programmed Stimulation and Ejection Fraction, and Relation to Outcome

MICHAEL G. KIENZLE, MD, JOHN U. DOHERTY, MD, DENIS ROY, MD,
HARVEY L. WAXMAN, MD, FACC, ALDEN H. HARKEN, MD, FACC,
MARK E. JOSEPHSON, MD, FACC

Philadelphia, Pennsylvania

The inducibility of ventricular tachycardia by programmed stimulation was correlated with ventricular ectopic activity on ambulatory electrocardiogram, ejection fraction and clinical outcome in 36 patients after endocardial resection for medically refractory ventricular tachycardia. Ventricular tachycardia was noninducible postoperatively in 25 patients and was inducible in 11. After administration of antiarrhythmic drugs, ventricular tachycardia could no longer be induced in four patients and remained inducible in the other seven patients.

All 36 patients had postoperative and 20 had preoperative ambulatory electrocardiograms obtained while they were not receiving drug therapy. Pre- and postoperative ambulatory electrocardiograms did not differ in mean hourly ventricular premature depolarization frequency, Lown arrhythmia grade or change in grade (pre- vs. postoperative). The majority of postoperative patients had repetitive forms of ventricular arrhythmia postoperatively and there was no difference between patients with inducible and noninducible ventricular tachycardia in regard to Holter monitoring characteristics. There was no significant difference in postoperative ejection fraction between patients with inducible and noninducible ventricular tachycardia postoperatively. Ventricular tachycardia has recurred in 2 of 29 patients who had no inducible tachycardia at the time of hospital discharge and were followed up for a mean of 1 year; it has recurred in one of seven patients in whom it was still inducible at the time of hospital discharge and who were followed up for a mean of 7 months.

It is concluded that: 1) the performance of subendocardial resection does not affect the level of ventricular ectopic activity; 2) ventricular ectopic activity measured by postoperative 24 hour electrocardiographic monitoring is not related to postoperative inducibility of ventricular tachycardia; and 3) the presence of inducible ventricular tachycardia despite antiarrhythmic therapy or high grade ventricular ectopic activity does not preclude a good outcome after subendocardial resection for refractory ventricular tachycardia.

The potential life-threatening nature of recurrent sustained ventricular tachycardia has prompted efforts to reliably assess the efficacy of therapy. Both programmed electrophysiologic study and ambulatory electrocardiographic techniques have been applied to this problem (1–6).

Endocardial resection has become a successful mode of therapy in patients with medically refractory ventricular tachycardia (7–9). The best way to judge surgical efficacy has not been established. We therefore evaluated the relation of ambulatory electrocardiogram findings, results of electrophysiologic studies and postoperative ejection fraction to surgical success in a group of 36 patients who had undergone endocardial resection for ventricular tachycardia.

From the Clinical Electrophysiology Laboratory, Hospital of the University of Pennsylvania, Cardiovascular Section, Department of Medicine, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania. This study was supported in part by grants HL24278 and HL22315 from the National Heart, Lung, and Blood Institute, Bethesda, Maryland; grants from the American Heart Association, Southeastern Pennsylvania Chapter, Philadelphia, Pennsylvania; and the Fannie E. Ripple Foundation, Morristown, New Jersey. Dr. Roy was supported by a grant from the R Samuel McLaughlin Foundation, Toronto, Ontario, Canada, and Dr. Josephson was a recipient of Research Career Development Award HL00361 from the National Heart, Lung, and Blood Institute. He is the Robinette Foundation Associate Professor of Medicine (Cardiovascular Diseases), University of Pennsylvania School of Medicine. Manuscript received February 15, 1983; revised manuscript received June 13, 1983, accepted June 15, 1983

Address for reprints: Mark E. Josephson, MD, Cardiovascular Section, 6 Ravdin, Hospital of the University of Pennsylvania, 3400 Spruce Street, Philadelphia, Pennsylvania 19104.

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Methods

Study group. Thirty-six patients who had undergone endocardial resection for recurrent sustained ventricular tachycardia and in whom postoperative ambulatory electrocardiograms were available while they were not receiving antiarrhythmic drugs constituted the study group. This group consisted of 27 men and 9 women with a mean age of 55 years (range 23 to 69). In 33 patients the underlying cardiac diagnosis was ischemic heart disease; 1 patient each had congestive cardiomyopathy, idiopathic aneurysm and hypertrophic cardiomyopathy with aortic valve replacement. Endocardial resection was performed in all patients, aneurysmectomy in 32 and coronary artery bypass grafting in 20 (mean of 1.6 grafts per patient). Two patients had mitral valve replacement. The details of the preoperative electrophysiologic evaluation, surgical procedures and postoperative evaluation of these patients have been previously described (7,8).

Electrophysiologic studies. Postoperative programmed electrophysiologic studies were performed 1 to 3 weeks postoperatively in the absence of antiarrhythmic drug therapy in all patients, except four, who had spontaneous recurrence of ventricular tachycardia in the early postoperative period before discharge. These four patients were evaluated while receiving antiarrhythmic drugs. These studies consisted of introducing up to three ventricular extrastimuli during ventricular pacing at two or more cycle lengths, and rapid pacing at one or more right or left ventricular sites, or both. Ventricular tachycardia was considered inducible if a sustained (>30 seconds' duration or requiring cardioversion for hemodynamic collapse) tachycardia of uniform morphologic features could be reproducibly initiated by programmed stimulation. The tachycardia was classified as clinical if it had a cycle length, axis and configuration similar to those of the spontaneously occurring tachycardia, or to the tachycardias induced preoperatively. If not observed preoperatively, the tachycardia was classified as nonclinical.

Ambulatory electrocardiography. In addition to continuous postoperative telemetric monitoring, each patient had at least 24 hours of ambulatory electrocardiographic recordings in the absence of antiarrhythmic drug therapy (except for three or four patients with a spontaneous postoperative recurrence of ventricular tachycardia who underwent programmed stimulation and 24 hour electrocardiogram while receiving a type I antiarrhythmic agent). The ambulatory electrocardiographic system utilized was an operator-assisted superimposition type. In 20 patients, preoperative ambulatory electrocardiographic data were also available while they were not receiving antiarrhythmic medications (or were on the same regimen as postoperatively in 1 patient).

The recordings were graded by a modified Lown classification (10) as follows: Grade 0, no ventricular premature depolarizations in a 24 hour recording; Grade 1, less than 30 premature ventricular depolarizations per hour of a uniform configuration; Grade 2, 30 or more premature ventricular depolarizations per hour of a uniform configuration; Grade 3, multiform ventricular depolarizations; Grade 4A, ventricular couplets; and 4B, ventricular tachycardia consisting of three or more beats. For each recording, the mean number of ventricular premature depolarizations per hour was calculated and log-converted for statistical analysis.

Ejection fraction. Postoperative left ventricular shape and function were routinely assessed by angiography at the time of follow-up electrophysiologic study and were available for 27 patients. Ventriculography was not available in the remaining patients for clinical or technical reasons. The ejection fraction was calculated utilizing the single plane area-length method.

Follow-up. Follow-up data were obtained by telephone interview and stressed recurrence of ventricular tachycardia, other symptomatic arrhythmias and any change in antiarrhythmic medications. If death had occurred, the circumstances were obtained from the patient's family or personal physician.

Statistical analysis. Data are presented as mean values ± standard deviation. Mean values were compared for statistical significance using Student's *t* test for paired or unpaired data where applicable.

Results

Electrophysiologic studies (Table 1). Ventricular tachycardia was noninducible by postoperative programmed stimulation in 25 of the 36 patients. All 25 patients underwent right ventricular stimulation, and 19 underwent left ven-

Table 1. Results of Pre- and Postoperative Ventricular Stimulation for 36 Patients With and Without Induced Sustained Ventricular Tachycardia at Initial Electrophysiologic Test Postoperatively

	Patients With No Inducible VT Postop		Patients With Inducible VT Postop	
Patients (no.)	Preop	Postop	Preop	Postop
RV stimulation	24	25	11	10
T-VPD	5	18	3	4
LV stimulation	1	19	0	4
T-VPD	0	7	—	2
Induced VT morphologies	1.9 ± 1.1	—	1.7 ± 0.5	1.1 ± 0 3
Mean CL (ms)	325 ± 83	—	323 ± 66	319 ± 111

CL = cycle length; LV = left ventricular; RV = right ventricular; Postop = postoperative; Preop = preoperative; T-VPD = triple ventricular depolarizations; VT = ventricular tachycardia.

tricular stimulation. The remainder were usually excluded from left ventricular stimulation for anatomic reasons (left ventricular thrombus, difficult arterial access, for example). The stimulation protocol was more rigorous (an additional extrastimulus or stimulation of left ventricle) than the preoperative study in 22 of 25 patients and similar in 2. Incessant ventricular tachycardia precluded preoperative study in one patient. Patients without postoperative inducible ventricular tachycardia were discharged on no antiarrhythmic agents, except one patient discharged on procainamide therapy for postoperative atrial flutter.

Ventricular tachycardia was inducible by programmed stimulation in 11 of 36 patients (Fig. 1). The four patients who had a spontaneous recurrence of ventricular tachycardia in the early postoperative period before hospital discharge were included in this group. Left ventricular stimulation was performed in only 4 of these 11 patients. Ventricular tachycardia was inducible with right ventricular stimulation alone in the remaining six patients. More vigorous stimulation was required to induce ventricular tachycardia in six patients, stimulation similar to the preoperative protocol in four and the mode of stimulation could not be compared in one patient with frequent spontaneous episodes of tachycardia postoperatively. No patient had a tachycardia induced with rapid pacing. In two patients, a ventricular tachycardia not previously seen spontaneously or in the clinical laboratory was induced (nonclinical). In these two cases, two or three left ventricular extrastimuli were delivered close to ventricular refractoriness after ventricular pacing at a cycle length of 400 ms. In contrast, ventricular tachycardia had been easily inducible preoperatively in each patient with double ventricular extrastimuli from the right ventricle.

On follow-up study, ventricular tachycardia became noninducible in four patients receiving antiarrhythmic drugs (including both nonclinical tachycardias). Three of these patients were discharged on treatment with procainamide and one on treatment with quinidine. Ventricular tachycardia remained inducible in seven patients who at discharge were receiving the following agents: amiodarone plus a type I agent and an antitachycardia pacemaker (two patients); amiodarone and type I agent (one patient); type I agent alone (three patients); and amiodarone alone (one patient).

Ambulatory electrocardiography. The 24 hour electrocardiographic findings in the 20 patients with both pre- and postoperative recordings are shown in Figure 2. In both the pre- and postoperative periods, most patients exhibited the highest grades of ventricular arrhythmia. Preoperatively, 14 of 20 recordings revealed grade 4A or 4B arrhythmia. Postoperatively, 10 of 20 manifested these two grades. Figure 2 also illustrates that little overall improvement in grade of arrhythmia occurred postoperatively (8 of 20 recordings manifested the same grade, 6 of 20 a more complex grade and 6 of 20 a less complex grade). There was no significant difference in mean ventricular premature depolarizations per hour between pre- and postoperative groups (218 ± 375 vs. 363 ± 530 per hour, mean ± standard deviation, probability [p] > 0.05). Only one patient exhibited a postoperative decrease in ventricular premature depolarizations per hour of greater than 83%. This patient subsequently died suddenly.

The postoperative 24 hour electrocardiographic findings are shown in Table 2 for all 36 patients. The distribution of patients within the modified Lown scale shows the majority of patients had grades 4A and 4B arrhythmia, and is similar to the distribution of postoperative findings for the 20 patients who had both pre- and postoperative ambulatory electrocardiographic monitoring. Furthermore, when patients are grouped according to inducibility by initial programmed stimulation postoperatively, there is no difference in severity of ventricular arrhythmia between these groups (56% without and 54% with inducible tachycardia, respec-

Figure 1. Results of postoperative electrophysiologic testing. After subendocardial resection, ventricular tachycardia could not be induced (non-ind) by programmed stimulation in 25 patients and was still inducible (ind) in 11. After administration of antiarrhythmic agents, tachycardia was not inducible in four patients and was still inducible in seven.

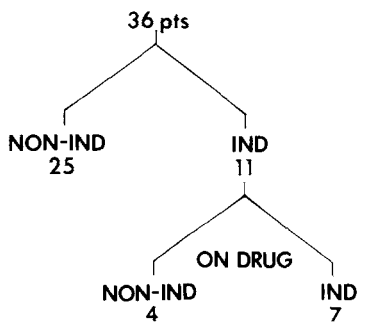


Figure 2. The results of Holter ambulatory electrocardiographic monitoring performed pre- and postoperatively in 20 patients undergoing subendocardial resection. The modified Lown grades of ventricular arrhythmia (see text) and the mean number of ventricular premature depolarizations per hour (VPD/h) are shown.

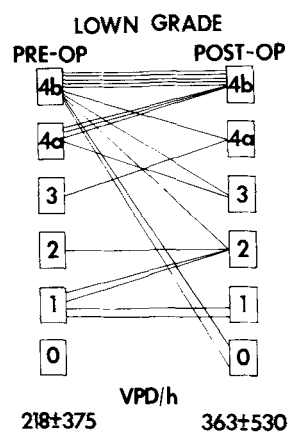


Table 2. Postoperative Ambulatory Electrocardiographic Findings for Patients With Noninducible (Non-Ind), Inducible (Ind) and all Postoperative Patients

Lown Arrhythmia Grade	Non-Ind (n = 25) (%)	Ind (n = 11) (%)	All Patients (n = 36)(%)
4B	10 (40)	3 (27)	13 (36)
4A	4 (16)	3 (27)	7 (20)
3	4 (16)	1 (9)	5 (14)
2	2 (8)	1 (9)	3 (8)
1	4 (16)	1 (9)	5 (14)
0	1 (4)	2 (19)	3 (8)
VPD/h	244 ± 463	77 ± 188	202 ± 411

VPD/h = ventricular premature depolarizations per hour.

tively). The mean number of ventricular premature depolarizations per hour was not significantly different in the inducible and noninducible groups (77 ± 188 and 244 ± 13 per hour, respectively, not significant).

Ejection fraction. The mean postoperative ejection fraction for the patients with noninducible tachycardia postoperatively was 41 ± 13% and was not significantly different from that for the group with inducible tachycardia (44 ± 6%).

Follow-up. A total of 29 patients were discharged without inducible ventricular tachycardia, either with or without antiarrhythmic therapy. In this group of patients, there were five deaths and two recurrences of tachycardia over a mean follow-up period of 12.9 ± 10.1 months. Two deaths occurred after acute myocardial infarction and two paients died of heart failure. In one patient, death occurred suddenly during performance of yard work and was considered an arrhythmic death. This patient, with no inducible ventricular tachycardia postoperatively, demonstrated complete abolition of ventricular arrhythmia on ambulatory electrocardiographic monitor (grade 4B arrhythmia preoperatively and grade 0 postoperatively). One patient, discharged with no inducible tachycardia on quinidine therapy, has had a recurrence while receiving that drug. This patient continued to take quinidine, which keeps him nearly symptom-free during infrequent episodes of ventricular tachycardia.

Of the seven patients discharged with ventricular tachycardia still inducible on a drug regimen, two have died in a follow-up period of 7.5 ± 5.2 months. One patient died of pneumonia and the other had recurrence of ventricular tachycardia before dying of congestive heart failure. Therefore, ventricular tachycardia has recurred in 2 of 29 patients without inducible tachycardia (with or without drug therapy) and in 1 of 7 patients in whom tachycardia was still inducible at hospital discharge.

All four patients with early recurrence of ventricular tachycardia before hospital discharge were sent home on antiarrhythmic drug therapy (tachycardia was still inducible in two patients). One of these patients (no inducible tachycardia with quinidine) has also had a late recurrence. A summary of the postoperative findings for the three observed late recurrences is shown in Table 3. Using the ventricular tachycardia inducibility at the time of hospital discharge, the negative predictive value of electrophysiologic study was 93%, but the positive predictive value was only 14% (Fig. 3).

Discussion

Role of electrophysiologic studies. Programmed electrophysiologic studies have been widely used to determine drug and pacemaker efficacy in the treatment of recurrent ventricular tachycardia. These studies have proved predictive of success or failure of therapy (2–4). Endocardial resection has been a successful intervention in patients with medically refractory recurrent sustained ventricular tachycardia (7–9). After surgery, the need still exists to identify patients at risk for recurrence of ventricular tachycardia. Our results suggest that failure to induce ventricular tachycardia postoperatively is associated with a low incidence of clinical recurrence. It should be noted, however, that recurrence of ventricular tachycardia was relatively infrequent over a short follow-up period in the small group of patients with tachycardia still inducible at hospital discharge. This observation is somewhat different from observations made by previous investigators (2–4) who have stressed the high incidence of recurrence of ventricular tachycardia in medically treated patients in whom tachycardia remains inducible on the eventual discharge regimen.

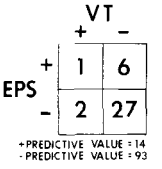
Four of seven patients with still inducible tachycardia

Figure 3. Predictive value of electrophysiologic testing (EPS) after subendocardial resection. A 2 × 2 diagram shows ventricular tachycardia inducibility at hospital discharge and clinical recurrence of ventricular tachycardia (VT) after discharge. EPS + denotes inducible ventricular tachycardia at electrophysiologic testing and VT + clinical recurrence after discharge. The number of patients in each of the four possible categories is shown in the **boxes.** The derived true and false positive and negative values of electrophysiologic testing are as follows:

$$\text{Positive predictive value} = \frac{TP}{TP + FP} = \frac{1}{1 + 6} \quad (14\%)$$

$$\text{Negative predictive value} = \frac{TN}{TN + FN} = \frac{27}{27 + 2} \quad (93\%),$$

where FN and TN = false negative and true negative, respectively, and FP and TP = false positive and true positive, respectively.



were discharged on amiodarone therapy. Clinical success with amiodarone, unlike that with other antiarrhythmic drugs, may not correlate with the results of electrophysiologic study (11,12), and this may, in part, explain the low positive predictive value of postoperative electrophysiologic testing in this group of patients. The possibility also exists that postoperatively, local left ventricular tissue properties gradually change and the tachycardia may become noninducible with time. Late electrophysiologic studies in these patients have not been evaluated.

Recent studies (13,14) have demonstrated that vigorous modes of ventricular stimulation may induce nonclinical ventricular tachycardia. These tachycardias are often polymorphic and nonsustained and may have no clinical significance. The prognostic importance of induced uniform, sustained, but nonclinical tachycardia, as in our two postoperative patients, remains unsettled. Therefore, the relative contributions of endocardial resection, mode of stimulation, traditional antiarrhythmic agents and amiodarone to clinical outcome are not absolutely known in these patients.

Role of ambulatory electrocardiography. In patients with ischemic heart disease, there is a correlation between severity of ventricular arrhythmia and the extent of coronary artery disease (15,16). The preoperative ambulatory electrocardiographic findings in our patients illustrate the high prevalence of complex ventricular arrhythmia in patients with extensive coronary artery disease, prior infarction and life-threatening ventricular arrhythmias. It is likely that with additional periods of monitoring, all or nearly all patients would have the most severe grades of arrhythmia. Postoperatively, high grade ventricular arrhythmia persists in our patients, and relates neither to inducibility of ventricular tachycardia nor to long-term clinical outcome. Others have noted persistence of ventricular arrhythmia despite successful surgical and medical therapy of ventricular tachycardia (1,7,8,17). Our studies lend further support to the concept that successful endocardial resection depends on interruption of the reentrant tissue rather than abolishing the trigger stimuli.

Relatively few studies have directly compared the utility of programmed stimulation and ambulatory electrocardiographic monitoring in the management of recurrent symptomatic ventricular tachycardia. Two recent reports have found the ambulatory electrocardiogram unreliable compared with programmed stimulation for predicting efficacy of drug therapy in patients with ischemic and nonischemic heart disease, while others have found the technique useful in guiding antiarrhythmic therapy (4–6). Our studies suggest that ambulatory electrocardiographic monitoring adds little to the postoperative management of patients undergoing endocardial resection.

Contribution of ventricular dysfunction. In patients with ischemic heart disease, left ventricular dysfunction and ventricular arrhythmias are closely related (15,16). Myocardial damage resulting from previous infarction is the substrate for both. Postoperative ejection fraction, used as a rough indicator of left ventricular function, does not appear to discriminate between groups with inducible and noninducible ventricular tachycardia postoperatively. The ejection fraction in the small group of patients with ventricular tachycardia recurrence were similar to those without recurrence. Improvement in some indicators of ventricular function occurs in patients undergoing endocardial resection and aneurysmectomy for ventricular tachycardia (18). The contribution of improvement in left ventricular size and function to successful arrhythmia control awaits further study.

Conclusions. We evaluated the relation of postoperative electrophysiologic study, ambulatory electrocardiographic studies, ejection fraction and ventricular tachycardia recurrence in 36 patients who had undergone endocardial resection for medically refractory ventricular tachycardia. We conclude that: 1) performance of endocardial resection does not affect the level of ventricular ectopic activity measured by ambulatory electrocardiography; 2) the level of ventricular ectopic activity measured by postoperative ambulatory electrocardiography is unrelated to inducibility of ventricular tachycardia by programmed stimulation; 3) ejection fraction is similar in patients with inducible and noninducible ventricular tachycardia after endocardial resection; and 4) the presence of postoperative inducible ventricular tachycardia or high levels of ventricular ectopic activity does not preclude a good outcome after subendocardial resection.

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Table 3. Late Recurrence of Ventricular Tachycardia in Three Cases

Case	EPS	Postop Lown Grade	Ejection Fraction (%)
1	NI	0	39
2	NI with quinidine	4A	49
3	Ind with procainamide	4B	40

EPS = eletrophysiologic testing; Ind = inducible tachycardia; NI = noninducible tachycardia; postop = postoperative.

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